DOCUMENT RESUME

ED 124 135 IR 003 523

AUTHOR Avner, R. A.
TITLE An Evaluation-Oriented Approach to Production of Computer-Based Instructional Material.
INSTITUTION Illinois Univ., Urbana. Computer-Based Education Lab.
REPORT NO CERL-X-14
PUB DATE [75]
NOTE 41p.; Not available in hard copy due to poor quality of original print

EDRS PRICE MF-$0.83 Plus Postage. HC Not Available from EDRS.
DESCRIPTORS Behavioral Objectives; *Computer Assisted Instruction; Higher Education; *Instructional Materials; Instructional Systems; *Material Development; On Line Systems; *Production Techniques

ABSTRACT

This manual provides information for the preparation of material for presentation by computer-based instructional systems. The following topics are discussed: the advantages of computer-based education (CBE); the requirements for basic learning; the importance of behavioral objectives in CBE; specific types of CBE systems; use of on-line data; "off-line" sources of evaluation; construction of CBE materials; student introduction to CBE; and documentation of materials. For further information, three books are cited. (EMH)

****
* Documents acquired by ERIC include many informal unpublished *
* materials not available from other sources. ERIC makes every effort *
* to obtain the best copy available. Nevertheless, items of marginal *
* reproducibility are often encountered and this affects the quality *
* of the microfiche and hardcopy reproductions ERIC makes available *
* via the ERIC Document Reproduction Service (EDRS). EDRS is not *
* responsible for the quality of the original document. Reproductions *
* supplied by EDRS are the best that can be made from the original. *
****

91
X-14
IR

ED124135

AN EVALUATION-ORIENTED APPROACH TO PRODUCTION OF COMPUTER-BASED INSTRUCTIONAL MATERIAL

R. A. AVNER

COMPUTER-BASED EDUCATION RESEARCH LABORATORY

UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

BEST COPY AVAILABLE

PERMISSION TO REPRODUCE THIS COPYRIGHTED MATERIAL HAS BEEN GRANTED BY

CERL

TO ERIC AND ORGANIZATIONS OPERATING UNDER AGREEMENTS WITH THE NATIONAL INSTITUTE OF EDUCATION. FURTHER REPRODUCTION OUTSIDE THE ERIC SYSTEM REQUIRES PERMISSION OF THE COPYRIGHT OWNER.

U.S. DEPARTMENT OF HEALTH, EDUCATION & WELFARE
NATIONAL INSTITUTE OF EDUCATION

THIS DOCUMENT HAS BEEN REPRODUCED EXACTLY AS RECEIVED FROM THE PERSON OR ORGANIZATION ORIGINATING IT. POINTS OF VIEW OR OPINIONS STATED DO NOT NECESSARILY REPRESENT OFFICIAL NATIONAL INSTITUTE OF EDUCATION POSITION OR POLICY

IR003523

ACKNOWLEDGEMENTS

While responsibility for the statements made and conclusions drawn in this manual rest with the author alone, I would be remiss in not acknowledging the immense contribution made over the past 10 years by my association with members of the staff of the PLATO project (first with the Coodinated Science Laboratory and later with the Computer-based Education Research Laboratory) and over 100 authors of material for the PLATO Computer Based Education system. Much also is owed to interaction with members of many specialized groups at the University of Illinois including the Center for Instructional Research and Curriculum Evaluation and the Curriculum Laboratory.

CONTENTS

Introduction..... 1

The Instructional Process..... 4

Instructional Objectives..... 7

Specific CBE Systems.....13

Why CBE?.....16

Use of "On-Line" Data.....18

"Off-Line" Sources of Evaluation Data.....23

Construction of CBE Materials.....28

Introducing the Student to CBE.....30

Documentation.....34

For Further Information.....37

AN EVALUATION-ORIENTED APPROACH TO PRODUCTION OF COMPUTER-BASED INSTRUCTIONAL MATERIAL

A Brief Manual

This manual is designed for use by persons (generally teachers or other subject-matter experts) who are starting to prepare material for presentation by computer-based instructional systems. It attempts to provide such individuals with an overview of general techniques and practical considerations which have been found important for efficient and effective use of the medium. It is not intended to provide an exhaustive guide to use of computer-based education (CBE) but rather a means by which the new author of CBE materials can rapidly begin gaining direct experience with the medium without making the more expensive or time-consuming blunders already made by his predecessors.

No matter what medium is used, instruction has enough of an artistic element that nothing quite replaces early and extensive practice. It is assumed, and earnestly hoped, that the new CBE author will be motivated to expand his or her initial formal knowledge of instructional and evaluational techniques as proficiency and need dictate (for this reason, the references listed in the manual have been selected with the aim of providing maximally useful entry points to the extensive literature in these fields). However it is felt that, at the practical level, instructional techniques are best learned through thoughtful use of the information provided by one's own students. It is very strongly felt by the author that a true CBE system provides the author with an almost unique chance to engage in such a learning experience. The true CBE system provides this advantage by making possible two critical functions:

(1) *Timely* collection and processing of *complete* student data, and

(2) Provision for *rapid, inexpensive* change in lesson material.

The first function provides the author-teacher with the same "immediate feedback" deemed necessary for learning by students. Every experienced teacher is well aware of how relatively little information suitable for modification of instruction is received from students during most classroom instruction. If anything has been well taught to students in the course of the usual formal education, it is the ability to look attentive when one is not. Moreover, it is almost impossible for a teacher to interact extensively enough with every one of 20, 40 or 100 students in a class to obtain a clear view of the current status of learning for each student. The logistics of processing homework papers and tests can prevent deficiencies in teaching (or learning) from being identified until hours, days or weeks have passed. With the advent of the computer as intermediary between student and instructional material this situation can however be greatly changed. Properly designed CBE material requires the student to demonstrate proficiency many times during each class session. For the past several years, true CBE systems have permitted instructors to observe the results of these interactions immediately after or even during a class. Since the computer easily performs the clerical work of processing and collating this information, the author-instructor is rapidly made aware of the effectiveness of each segment of instruction with minimum effort. In short, the author has facts and the time needed to use them.

The second function provides the author with the means for making effective use of information. CBE instructional material generally exists in the form of a simple set of computer instructions. A change to this single copy instantly changes the form of the material for all subsequent students. A true CBE system permits such changes to be made by the author using easily available equipment in a matter of seconds. So-called CBE systems which require the aid of a highly qualified computer programmer, use of special editing terminals, or delays of minutes or hours before the effects of changes can be observed do not provide this

second function. Nor, unfortunately, do media using sequentially stored information (such as video or audio tape) when extensive amounts of material are involved. The major consideration in making a change in instructional material should be the expected effectiveness of the change rather than the difficulty or time required to make it. True CBE minimizes the difficulty/time barrier to making changes.

Obviously many currently used instructional approaches permit rapid, easy change of content (e.g. a lecture) and some approaches even permit both functions (e.g. a one-to-one teacher-student ratio) however no medium but CBE currently has promise of providing both functions economically for large numbers of students.

Of course there is more to evaluation than collecting massive amounts of student data via computer and there is more to writing instructional material than making random changes in older material. We will now turn to these practical matters.

THE INSTRUCTIONAL PROCESS

In practice the instructional process is too often characterized by one of two extreme approaches which tend to inhibit development of successful learning. These two extremes may be labeled the "academic" and the "training" approaches.

The "academic" approach holds that "presentation is equivalent to instruction." Users of this approach would claim that if *any* student is able to demonstrate learning then the presentation is adequate. Those who fail to learn are not trying, are not adequately prepared, or are incapable of handling material at the level presented.

The "training" approach, on the other hand, holds that "if the student fails to learn, the teacher has failed to teach." If *any* student fails to demonstrate learning, the teaching has been inadequate.

Both approaches are of course oversimplifications. Both fail to recognize that teaching is not simply a matter of assigning responsibility. Neither attends to other factors which affect the success of the instructional process. Before proceeding to details of use of CBE it might be worth reviewing these factors as well as some other aspects of instruction that are applicable to all media.

Three basic requirements. No experienced teacher (nor, for that matter, any person who has ever learned anything) will be surprised at the sorts of things research and practice have shown to be necessary for effective learning. The only surprising thing is that these rather common-sense notions are so frequently ignored in formal instruction. The lists below are neither complete nor authoritative indications of the status of instructional research. Rather they represent factors which the author has found useful as general guidlines in designing instructional sequences.

(1) *The student must be aware of the relevant information.* It is exceedingly unlikely that *efficient* learning will result if the student is not made to recognize the presence of the appropriate information. It is not necessary that attention be explicitly called to the information (e.g. "memorize these definitions") or "notice that this spelling has been scored wrong" but it does appear necessary that students be made to attend to it in some way. Certainly little is to be gained by keeping the student unaware of what it is that he is expected to learn. Note that rapid information feedback (mentioned above) is one aspect of this requirement.

(2) *The student must possess all skills necessary for proper use of the new information.* A person who cannot read is unlikely to benefit from knowing that directions for using a medicine are printed on the label. Very little instruction is done on the assumption that nothing is know by the student, yet very few teachers take the time to determine that prerequisite skills assumed present are indeed present. An instructional segment may fail either because of its content or because it presumes skills which the student does not have.

(3) *The student must use the information.* New information is best retained if it is used by the student in some fashion which forces the information to be related to previous knowledge. Best learning seems to occur when the student discovers these relationships himself but teacher-provided structuring is next best and much better than presentation of each new item of information as if it were an isolated bit of nonsense to be learned by rote. Learning is also enhanced if use of the new information occurs in a variety of situations which are separated in time by engagement with other activities.

Three facilitative factors. Once the three requirements listed above are met, a host of other factors will begin to show effects on learning. Three such factors which seem to arise frequently in good instructional sequences are listed below.

(1) *The learning task should be of moderate difficulty for the student.* Tasks which appear extremely difficult may simply be avoided by the student. On the other hand the student may avoid attending to tasks which appear so easy that they are seen as not requiring effort. An especially insidious situation also arises when the student avoids performing a long sequence of seemingly simple learning tasks. At some point the cumulative number of simple but uncompleted tasks becomes an overwhelming task in itself and the student may avoid all further effort.

(2) *The student should feel that mastery is possible and desireable.* Solution of learning tasks should contribute to the student's feeling of competence in the subject matter and in dealing with novel situations in general. Note that such competence feelings are not likely to result from solution of a series of simple tasks which require minimal effort. Tasks must provide real challenges, be mastered as a result of a significant degree of understanding on the part of the student, and be rewarded in a manner such that the student feels that the effort was worthwhile. Whenever possible, error feedback should be an intrinsic part of the problem rather than an extrinsic judgement provided by the instructor. Life does not provide a set of answers at the back of the book.

(3) *The information should be of value to the student.* Every effort should be made to relate every step of learning to problems of direct interest to the student. Even where this is not possible, the information should appear in a setting which involves humor, surprise, contrast, pleasant design or other elements which contribute to human interest.

In each of the six considerations listed above, CBE is able to make a useful contribution to the instructional process. Basic is the fact that CBE offers individualization of instruction. Frequent overt interaction between student and CBE system means that material can be designed which

(1) requires that the student demonstrate learning before each new item of information is presented,
(2) tests for presence of prerequisite skills and provides remediation or alerts the instructor before continuing,
(3) provides sophisticated simulations which allow application of new learning in situations which approach those of "real life."

Because CBE allows both sequencing and structure of the material to be automatically adjusted for each student as a function of characteristics of that student (e.g., past performance and learning rates), CBE does not face the difficulties of other media which must attempt to provide a single instructional approach which is optimal for an audience having a wide range of backgrounds.

At the same time CBE does have limitations. The fact that extensive individualization is possible does not necessarily mean that this individualization can easily be provided (nor that it is necessary for effective instruction). More important, an ultimate aim of much instruction is the production of humans who seek and competently cope with novel situations in "real life." A major factor in production of the requisite skills and attitudes for such competency appears to be the presence of a "competency model" - a person with whom the student can identify who displays this competence. While a CBE terminal is quite competent in the role of "expert information source," it fails to provide anything close to a realistic model of a human enjoying the act of grappling with a novel problem.

INSTRUCTIONAL OBJECTIVES

Instruction seldom takes place in the absence of external influences. Students do not have unlimited time for or deep scholarly interest in every subject they take. It should be no surprise then that students are keenly aware of the distinction between what an instructor *says* is important (from his viewpoint of the subject matter) and what *is* important (from the student's viewpoint of what is required to make a good grade). A History instructor may earnestly seek to teach the ability to "draw parallels between current events and historical events." If his examinations consist of items requiring the student to do nothing but regurgitate lists of names and dates, few students are likely to "waste" time by studying anything but lists of names and dates. Moreover, few colleagues of such an instructor are likely to believe that a student receiving an "A" in such a course has necessarily shown an ability to "draw parallels between current and historical events." Nor has our instructor any means of gauging his success in teaching his stated objectives.

A better approach is the statement of objectives in a form which makes clear how success is to be measured. An objective stated in such a manner is currently termed a "behavioral objective" since it explicitly says what sort of behavior a successful student would be able to engage in. As an example let us attempt to restate the objective ... "the student will draw parallels between current and historical events." While this task might require a knowledge of specific details (perhaps even lists of names and dates), something more than simple memory may be implied. If memory alone were an objective, statements of the form "the student will list from memory at least four parallels between the War of 1812 and the current war," would be more appropriate. Perhaps the statement "given two historical events, the student will independently use

appropriate library sources to obtain relevant details (giving proper reference citations) and identify major similarities and differences between the events" comes closer to what is intended. Subject to factors such as the student's prior knowledge of the events, the size of the library available, and the definition of "major similarities and differences" it is certainly possible that the statement describes a situation requiring the application of principles and skills rather than rote memory. An even more difficult objective *might* be stated as "given a description of an historical event not covered in the course, the student will cite a recent event and parallel elements of the two events." The word *might* is emphasized because the task could simply involve recall of facts studied about a recent event and recognition of parallels drawn by the instructor to other past events. In short, the student might have only to recognize that the "historical event not covered in the course" was very similar to several historical events which *were* described in the course as paralleling a specific recent event.

From the brief outline above, several conclusions may be inferred about behaviorally stated objectives:

(1) An objective properly stated in behavioral terms gives far more information about the level of difficulty of the objective than less explicit statements.
(2) Various intentional or unintentional forms of "teaching to the test item" may make success in reaching the objective a less impressive achievement than implied in the statement of the objective.
(3) As levels of conceptual difficulty go above rote memory, difficulty in describing appropriate and valid test situations increases rapidly.

One of the major arguments against use of behavioral objectives has to do with the very human tendency for people to avoid difficulties where possible. If is is difficult to write behavioral objectives that describe important instructional goals, such as the ability to analyze the structure of a philosophical argument, then teachers may write behavioral objectives only about

trivial goals. In order to avoid such problems it is well to keep in mind the full range of objectives which you might wish your material to meet, remembering that unless some attempt to measure those objectives is made, you will never know whether you are seriously attempting to reach them or just fooling yourself.

While it is to be hoped that the thought necessary for definition of a reasonable set of behavioral objectives will lead the instructor to a clearer notion of what is to be taught and how best to teach it, it should be realized that writing objectives is not an end in itself. The objectives are truly useful only as test devices to determine where or if changes in the instructional material are necessary. To expect superior material to result automatically from writing behavioral objectives is as naive as to expect improved production in a secretarial pool as a result of giving everyone a test of typing skill. In each case it is not the device (behavioral objective or typing test) itself that produces an effect but use of the information that results. The typing test will produce improved production only if its results are used, say, to give additional training to the poorer typists. The behavioral objectives will produce better instructional material only if the results of the tests that they imply are used to modify sections of the material which do not produce the desired effects.

Construction of behavioral objectives is basic to production of instructional materials that must be effective in the absence of a human instructor. While the classroom instructor may realistically hope to teach effectively by use of years of experience, a minimal lesson plan, a minimal set of partially defined objectives, and exploitation of opportunities which arise by chance in the course of student-teacher interaction, CBE material must be completely preplanned or chaos will result. The new author of CBE materials will

want to make use of the services of a person experienced in writing of objectives during the early stages of learning the process. One of the most important aspects of this learning process is recognition of the full range of factors which must be considered. A sampling of some of these factors will now be considered.

Overall intention. At the most general level we may consider several general objectives for the material to be designed. Some representative overall objectives include (but are not limited to):

(1) *Selection with minimal instruction.* In some training situations a very large number of trainees are available for a limited number of positions. The least costly training method (for those doing the training) may entail giving minimal instruction and dropping all but the best students as the training proceeds. In this manner only those most likely to complete the training with least effort are given advanced levels of training. Some form of this approach is implicit in all instruction in which grading or evaluation is based on relative performance with automatic elimination of those scoring below some relative level at each evaluation stage. The heavy cost in time of this approach for trainees who do not complete the instruction makes the approach generally unsatisfactory.

(2) *Mastery of fixed objectives.* Where individualization of instruction is possible, different students may be allowed to expend varying amounts of time and use varying resources to attain very high levels of performance (master) on fixed goals. In learning of complex tasks it may be very difficult for large numbers of students to achieve true mastery. In such instances "mastery" may be equated with some incomplete but high level of achievement such as performance at which the grade "B+" would have been assigned under a standard classroom intructional procedure. Unlike the selection approach, the mastery approach has no fixed percentage of students who will pass or fail and it is assumed that most students who meet the entry requirements for the instruction will achieve mastery.

Many combinations of the above overall objectives with other desired outcomes are possible. Thus, an instructor may seek to produce the same amount of learning currently provided but with reduced average time per student. If all instruction is normally done in a classroom, individualization alone may produce the desired savings since the classroom instruction must proceed at a rate well below the level of the average student in order to avoid leaving a major part of the class behind. Note that individualization alone would

probably not produce such effects for most college-level instruction where extensive amounts of learning are done by individual study outside the classroom.

Priority of objectives. Not all objectives are of equal importance. In one sense, some objectives may simply be considered to be of less value than others. It would be inappropriate to spend as much time on minor objectives as on the major objectives of an instructional sequence.

In another sense, complex skills are often based on many interdependent objectives which must be attained in a particular order. It would usually be a waste of time to attempt complete attainment of some complex skill before subordinate skills were possessed. Note that such a hierarchy is based on skills necessary for understanding rather than on some historical or logical pattern.

Depth of objectives. As suggested above, objectives are not limited to simple rote memory of facts. Most true education attempts to cover the full range of complexity of skills and attitudes. A useful checklist for the author who wishes to be sure that no important level of skill or attitude has been omitted from his list of objectives is contained in the reference edited by Bloom, Hastings, and Madaus which is cited on the last page of this manual. This checklist is an abbreviation of a much more exhaustive classification scheme which you may wish to look at later (references are contained in the same book). A simplified form of the checklist appears on the following page.

Objectives having to do with thinking

1. Knowledge-recall of specific facts, methods, relationships, etc.
2. Comprehension-ability to translate, interpret, or extrapolate from known information.
3. Application-use of an abstract principle or generalization in a specific situation.
4. Analysis-identification of elements, relationships between elements and principles of organization of a communication.
5. Synthesis-creation of a new communication, plan, or set of relationships from known information.
6. Evaluation-judgments of value based on objective use of internal evidence and external criteria.

Objectives having to do with attitudes

1. Receiving-willingness to observe with minimal or no resistance.
2. Responding-active attention on a voluntary basis with minimum positive feelings.
3. Valuing-shows consistent behavior related to worth of a concept.
4. Organization-perceives multiple-value situations and relationships among values.
5. Characterization-incorporates value relationships into own philosophy.

While the above list provides a widely accepted description of the different levels which might be considered in writing of objectives, there is no requirement that all elements of the list be included or that the list even be followed. What is important is that the author be aware of the full range of possibilities that might be selected as legitimate instructional objectives. Additionally it should be remembered that objectives need not be restricted to behaviors alone or even to students alone.

SPECIFIC CBE SYSTEMS

Though this manual is not directed toward use of any one CBE system, the importance of knowledge about the system to be used cannot be overemphasized. Once the basic decision as to *what* to teach has been made, the decision as to *how* to teach is strongly dependent on the media available. The author who chooses CBE solely on the basis of novelty or belief in some magical property of computers will soon discover that CBE is sufficiently flexible to allow dismal failure as well as dazzling success. The decision to employ CBE must be based on a clear idea of those features of the available system which make CBE the best medium for a particular instructional problem. Despite a growing literature which purports to describe the relationship of instructional and situational variables to successful use of "The Computer" in education, wide differences in available systems force one to use caution in generalizing from many reported findings.

A host of differences may be observed even among the devices used for communication between student and CBE system. Printing typewriter terminals are usually slow, noisy and have limited graphic capability but provide the student with a printed copy of his interaction with the instructional material. Electronic displays (such as TV) appear in great variety. Some are extremely flexible, allowing simultaneous viewing of superimposed computer-generated graphics and continuous-tone color photographs. Others are little more than silent typewriter terminals with limited character sets and minimal graphic capability.

Systems also differ enormously in the range and sophistication of possible logical, mathematical and student response-processing operations. In short, preparation of material "for CBE" as a generality can only imply preparation of material for the most limited system available. The author who is unacquainted with the capabilities of even such a limited system is indeed lost.

The fact that material produced by the author might be translated for CBE use by some intermediary person ("programmer," "coder," etc.) does not eliminate the need for the author to be aware of the limitations and potentialities of the system to be used. The author who feeds his ideas through such a human communications channel without a general idea of the manner in which the particular CBE system produces an instructional interaction may not only make inappropriate use of the medium but may also make inefficient use of his resources. At one extreme such an unenlightened author may innocently request effects which are inordinately difficult to produce using the CBE system available. A good programmer will be able to produce almost any effect desired but the cost in time may far exceed the value of the effect produced. At the other extreme, the naive author may become so impressed with the imagined or real difficulty in changing instructional approaches that a few rigid approaches will be used for virtually all instruction.

The degree of sophistication needed before a new author can begin effective use of CBE as a medium is actually quite modest. At the very minimum the author should be exposed to a wide variety of approaches using the intended CBE system. Such exposure may consist of reviewing a few hours of material written by several different experienced authors. This experience will reduce the likelihood that only a limited (and possibly ineffective) set of instructional approaches will be used by the new author. For example, a new CBE author with past experience in programmed instruction will often limit himself to approaches which fail to make use of stored historical data on each student's past performances. Another with experience in film or television might fail to make maximum use of the interactional capability of CBE.

The final and unending stage in the orientation of a new CBE author consists of learning how particular displays are produced and how given student-system interactions are effected. At first this information may be restricted to a vague

feeling for what sorts of effects are easily performed on the CBE system and what sorts of effects are difficult. Operations which can easily be done are available for flexible incorporation in all instructional sequences. Those which are more difficult are considered only if expected benefits outweigh the added cost in effort. Ideally, the author should become proficient enough to be *able* to produce most of his own material without relying on the use of an intermediary (though, for practical reasons, he may not actually *do* so). With the better CBE systems such an ideal is quite easily attained and the author who is forced to rely on programmers or coders to communicate with the system is a rarity.

WHY USE CBE?

CBE is an extremely flexible medium. However, so long as cost and availability limit student access to CBE, most authors will want to reserve CBE for tasks which make best use of its unique capabilities. Thus CBE should not be used solely because it is available or solely because a particular approach requires use of CBE (an alternative approach using another medium might provide better instruction). CBE is not a "treatment" or technique but rather a means of carrying out the desires of the author. Except to the extent that use of a particular medium limits an author in a crucial way, one medium cannot be said to be better or worse than another for some general application. To claim that, for example, sophisticated simulations are always best done by CBE is to deny man's infinite creativity in discovering new ways to err. Even in the absence of inept use of the medium, particular situations will rarely demand use of one and only one approach for effective instructions.

What CBE *does* do is permit the author greater latitude in trying different approaches. In the course of such trials it may well be that an approach using CBE is found more effective than all others attempted. It may even be the case that other authors discover that this same CBE approach is best of those methods attempted for their materials. Such findings do not imply that the approach is a foolproof key to success in every application but only that it is one more approach among several worth serious consideration.

With the above cautions in mind, let us consider the sorts of applications in which CBE might offer a unique advantage. Basic to all such applications is a need for rapid and frequent student interaction with the material. In addition,

one or more of the following requirements would be present.

1. *Complex computational or logical operations.* Such operations might be of a quantity or complexity that would preclude reliance on a human instructor or tutor.

2. *Storage, access, and use of extensive student historical data.* Such data would be used for routing or other forms of individualization based on information more complex than a score on a single test item or group of items.

3. *Interactive graphic, audio or other sensory output.* Instances where one of many sensory presentations must be generated (or, more rarely, selected) on the basis of one of a great many possible student responses.

4. *Processing of complex student responses.* Proper identification of student responses in the form of typewritten freely-constructed natural language messages, manipulation of interdependent physical objects (e.g. controls on electronic equipment),or human physiological data (e.g. heart-beat rates), may require the capabilities of a computer where large numbers of responses must be rapidly and accurately processed.

5. *Simulation of complex physical or theoretical systems.* Rapid and nontrivial simulations of complex systems are necessary if large numbers of students are to become realistically involved. The computer is almost uniquely capable of meeting such requirements.

6. *Presentations which can be characterized by a standard procedure.* Where the material is made up by following a set of unambiguous rules (e.g. producing an arithmatic drill on addition of 2-digit numbers), the rules may be used directly by the computer to generate the material as well as present it.

In addition to situations in which CBE might offer a unique advantage for production and presentation of material, there are approaches in which CBE might offer advantages only during the development of material. Important considerations here include:

(1) Ease in collecting certain student data for the revision process through use of a CBE system,
(2) Ease in modification of material during development by use of editing features of true CBE systems.
(3) Convenience in coordinating new material with segments of instruction already written for CBE.

Again it should be emphasized that CBE only serves to broaden the range of possible instructional approaches available to the author-instructor. There is no guarantee that a CBE presentation, will be superior to presentation by any other medium even if it uses an approach not possible with any other medium. The major advantage of CBE lies in the relative ease with which the author may gather information on the effectiveness of material and modify that material.

USE OF "ON-LINE" DATA

A major advantage of CBE is the fact that many interactions between student and material are represented by information which flows through the computer on its way to or from the student. This information may be automatically stored and/or processed by the computer at the time of the interaction (i.e., "on-line").

Once stored, such information may be used automatically as a part of the basis for making individualization decisions. It may also be used directly by the instructor for evaluating the instructional material or, after the material is known to be effective, evaluating individual student performance.

Although some CBE systems are severely limited in capacity or flexibility for data collection, for the true CBE system the major problem in on-line data use is not collection but selection. Enough information is generated by the interaction of just a few students with most CBE material to innundate the author. Most of this information is of little value since it represents execution of operations designed into the material. Thus, the fact that a student gave an anticipated answer of a given type is generally as useful as knowing exactly what that answer was. The same is not true of unanticipated responses. When a student gives an unexpected response, the author is very much interested in the exact response given. The response may be correct or it may be wrong. In either case it may still suggest a modification of the material.

The author who saves enormous amounts of data in hopes of finding something useful at some future time is both being unrealistic and failing to use the features of CBE to full advantage. All too often the analysis of large amounts of data is put off until it is too late to modify the collection

process to correct problems discovered, much less make full use of the data for modification of the material.

A far more effective approach is to think about a few major instructional problems that might be answered by data from students. Having identified one or more problems, several possible measures which might yield useful information specific to those problems should be isolated. These measures should be used on a daily basis during testing or revision of material for a period sufficiently long to determine their effectiveness in solving your problem. If data are only available after long delays (i.e., after the earliest convenient time for making revisions in the material) or only with great difficulty (i.e., requiring more than a few seconds to obtain), the data gathering process becomes a hindrance rather than an aid to production of material. A true CBE system should provide rapid, easy collection and access to data. Daily contact with the data in context with the instructional material should allow identification of features of the measures used which aid or hinder their usefulness. Modification of the measures or their method of collection should be made on a continuing basis until you feel that you have found a measure which is the best available for your purposes.

There are, unfortunately, no simple rules for what *data* will always be useful though the *problems* that the data are designed to solve do appear in almost all situations. These problems include:

(1) How can I tell if this material is teaching effectively?
(2) How can I be sure that a student at this point really should be given (or not given) remedial, recreational, enrichment, etc. material?

The data which best answer these questions will vary depending on the type of material, the presentation used, and your instructional goals.

In almost every instance the optimal measure will turn out to consist

of fairly simple data (although the manner in which the data are collected may be rather special). In some instances the best measure will be a straightforward representation of the data. The best estimate of the total time required for completion of a given portion of the material by some specified proportion of students is thus represented by the distribution of actual completion times for typical students. More frequently the best measure will consist of a relationship between two or more types of data. For example, learning is not necessarily related to low (or high) error rate, but it does appear, in certain situations, to be related to low numbers of *repeated* errors on the same problem. A measure based on the percentage of problems in which two or more errors were made will make a rather good index of learning ease for such material. Such a measure would obviously not make a good index for materials in which only one attempt was allowed for each problem. Nor would it make a good measure in any material designed to minimize errors by use of heavy prompting. Copying of measures found useful by other people without careful thought about the characteristics of your own material and needs will seldom prove useful.

Because of the importance of finding relationships between different types of data, it should be possible for the author to request easily and obtain rapidly graphic representation of the relationship between specified sets of data. The measure of learning described above was discovered when it was noticed that the relationship between "error rate" and "number-of-items-correct-on-first-attempt" for students using the material was linear for materials which seemed to teach well. Some thinking about why this should be true produced the simpler measure described above. Without the ability to manipulate the three or four pieces of data which seemed most likely to be related to learning of this material, identification of the final measure might have taken

a much longer time despite its rather common-sense nature. The seeming simplicity of many useful measure discovered only after a good deal of hard thinking and empirical testing may at first be disappointing, but many years of digging such measures from data has led to two generalizations by the author:

(1) If the resulting measure is so obvious that you feel like kicking yourself, it is probably a valid measure.
(2) If the resulting measure is so novel that it suggests a major breakthrough in educational technology, you have probably made a blunder somewhere.

Some generalizations. Having cautioned the reader about wholesale generalizations of on-line measures, we shall proceed to make some wholesale generalizations which seem to be more generally supported by experience than most.

One of the most attractive variables for on-line data collection is time. The computer is able to determine and store times between events with a great deal of precision and ease. Unfortunately, with the exception of a very restricted set of rather simple drill-type situations, data on times of short duration are almost always useless for any purpose. This is not true for time data of longer duration. It is almost always necessary for planning purposes to collect data on the total time spent working on material. Also in learning of rather complex skills which may involve work over many minutes, measures of time spent from first exposure to final demonstration of mastery (with many responses occurring between these events) is often a better measure of learning ability or difficulty than measures of errors made.

As was suggested above, analysis of wrong answers and unanticipated responses usually yields much more information than studies of correct responses. At the very lowest level, such information permits "polishing" of material so that as many student responses as possible are treated in an appropriate manner. It is obviously poor public relations to have correct student responses judged

"incorrect" because they were not anticipated by the author. Such polishing is necessary for good instructional material but is not sufficient to guarantee effective instruction. More work is necessary before real contributions to effectiveness are made. If possible, the reason for specific wrong or unanticipated responses should be determined. Usually this may be done by examination of the response and the context in which it was made. Sometimes careful questioning of a student will be required. If specific types of errors or misconceptions occur frequently, modification of the material will be warranted Care should be used in distinguishing between errors made where the student knows a test situation exists and those made where the student is in a learning situation. In the latter case it may well be that optimum learning will occur if everyone makes an "error" at one particular point and thus learns to be cautious in, say, overgeneralizing. In the test situation of course, consistent errors of one type are a warning that revision of some sort is necessary.

One final source of on-line data which may be overlooked is the student himself. It is generally possible to allow the student to enter comments about the material directly into the CBE system for storage during his time at the CBE terminal. Such comments serve both as a valuable source of information and as a means by which the student can "get back" at poorly designed material or malfunctioning equipment. Perhaps because these comments are directed at an inanimate object (the CBE system or the material), they tend to be much more frank than one could hope to get in a normal classroom situation.

"OFF-LINE" SOURCES OF EVALUATION DATA

Though an enormous amount of information can automatically be collected by the computer, it would be a great mistake to assume that all data for evaluation and revision will come from this source. "On-line" data (data produced as a direct result of the interaction between student and CBE system) is capable of saying things only about what you remembered to include in the material. It says nothing about students rushing happily (or ambling unhappily) to terminals at the start of a class. It says nothing about an instructor's unhappiness (or joy) about the manner in which a particular point is taught. All of these things constitute data which should be considered if a CBE lesson is to anything more than an academic exercise for its author.

Observing things yourself. The very first step in gathering evaluation data is observation of a single student working through the initial version of your material. This first student should be a "typical" representative of students who will be using the finished product (you will also of course want students who represent extremes of ability or interests from this same group to work through the material as individuals). Each student should be made to understand that

(1) he is doing a favor to the author,
(2) the CBE material rather than the student is being evaluated, and
(3) any comments made by students about the material will be appreciated.

Such an orientation indicates the true state of affairs to the student; should insure that the student will give the sort of information not revealed by direct interaction with the system; and finally, should not make the student expend an unusual amount of effort in learning. The role of the author-observer is to gather data in a manner which minimizes "instructional" aspects of his presence. Unless the material is to be used with an instructor present, the observer should give *no* aid unless it is absolutely clear that the student can make no further

progress without it. Notes should be made on all student comments and on points of ambiguity, errors in the material, or points where more material might be required. Again it should be stressed that the observer should volunteer absolutely no information or hints and should give no requested aid unless the material is to be used with an instructor present or unless it is clear that further progress would be impossible without such aid. On the other hand, the observer should appear eager to receive comments. No effort should be made to defend the material. If anything, the observer should give the impression that he is half-convinced that the material is in great need of revision and that negative comments confirm his own opinions. Where vague comments are given, the observer should express interest in the viewpoint and try to identify (perhaps by questions of his own) the precise basis for the comment. After each individual student has completed the material (and been thanked for his contribution to its revision), any gross errors identified should be corrected. After four to six individuals have used the material, the author should have sufficient basis for making more major modifications or additions to the material. Major modifications should rarely be done on the basis of interacting with only one or two students. Also the author will have gained enough of a feel for student responses to the material that small groups of students can be used without fear of losing observational data.

Opinions and comments expressed by students are always valuable data. However, when groups of students use the material it will no longer be possible to easily collect this information from each student in person. Use of questionnaires will help us need quite well. These questionnaires should:

(1) be anonymous, the material rather than the student is being evaluated;
(2) be brief, no more than three or four questions;
(3) be explicit, no question should be asked unless it will provide data for a specific change or will answer a specific question;

(4) be used frequently, opinions collected only at the end of a course are useful for overall evaluation of the material but are too late to be of value to those making them.

Using observations of others. Your instructional sequence might teach more things faster and better than anything else available but if an instructor misuses or refuses to use it or if colleagues, administrators, or a host of others whose opinions are respected are unimpressed, its value may never be recognized. The opinions and beliefs of these people are thus valuable data for the author who expects his material to be used. It is only human to want to defend the product of one's labors from misinformed attacks but such defense can lead to shutting off valuable sources of information if not done properly. It is always a good idea to specifically ask for suggestions for improvement or change rather than seeking general impressions. "What do you think of it?" tends to produce polite murmurs rather than useful information. Whenever a comment or opinion is expressed, indicate strong interest in the statement and ask for more specific details if the comment is vague. You should convey (and feel!) a sense of expecting useful information from the person making the comment. Initial comments or opinions will often not be overly useful. Some are made only to impress upon you the fact that the individual making them considers that he has some expertise in the area. Once you indicate that you share the belief (by seeking more information) it is much more likely that thoughtful comments will be produced. If nothing else, you will leave the impression of being a person who is willing to listen to good advice.

Some comments may indicate misinformation. While the misinformation should be corrected do not stop at that point. The "information" that you have received from such comments suggests that there may be something about the way your material is perceived that leads to such erroneous impressions. It may be worthwhile to correct details of your presentation or literature on your material or to add information

which will counteract commonly held misconceptions. A very common form of "misinformation" is the expectation that the material should teach something it was not intended to teach. While a well written instructor's manual should minimize such "errors," the misinformation is again information which should not be ignored. It may be that your material is avoiding an area for which aid is needed. You should be able to justify *not* covering an area for which there are strongly expressed needs as well as justifying the coverage that your material does give.

While the judgments and observations of teachers, administrators, or simply members of the interested public may not always explicitly appear in the manual or reports prepared for prospective users of your material, this information represents real data which should have a direct effect on the form that such documentation takes if not on the instructional material itself.

Using standardized tests. In some fields widely-used standardized tests are available and recognized as either good general indicators of ability in the subject-matter area (e.g. certain foreign language proficiency examinations) or as criteria for certification in a professional field (e.g. National or State Board examinations in Medicine). While objectives of your material may differ from or exceed those for such examinations, you and prospective users of your material will be interested in knowing how well students perform on the tests after completing your material. If your objectives differ greatly from those tested for, you may be quite happy simply to show that students who use your material perform at least as well as those who use more standard approaches. Of course you will then also want evidence from your own tests which indicate success in meeting your own objectives. If you are not aware of the availability of standardized tests in your own area, you will want to consult with your local expert in evaluation and testing for suggestions.

Other sources. The need for breadth in coverage of possible evaluation factors cannot be overemphasized. Every factor that goes into decision- or opinion-making by those involved in the use of the material is relevant evaluation data. Much information of this sort may be difficult to quantify. While such measures may pose problems in accurate interpretation, to ignore them because they are "subjective" or "unscientific" would probably lead to decisions which were more inaccurate than would result from the use of the uncertain data. A person experienced in educational evaluation will be able to suggest many such factors which might be appropriate in your situation. One such individual has produced a conceptual framework designed to remind the evaluator of the full range of such factors available (Stake, R. E., The Countenance of Educational Evaluation, *Teachers College Record,* 68, 1967, No.7, 523-540).

CONSTRUCTING CBE MATERIALS

A very common approach for new CBE authors is the production of extensive amounts of material prior to initial use by students. Only after completion is information from students collected to provide a "final polishing." The result is often of rather poor quality and almost always ends up requiring major revision. In second-guessing the needs of the student the new author often produces more than is necessary. If the extra material appears in unused remedial sequences little will be lost except the time wasted by the author. Typically, however, the extra material is encountered by many students who must spend more time than should be necessary to complete it. Such a situation is rather insidious. Since all students will probably do reasonably well on criterion tests, only possible student boredom and slow progress will indicate the author's (and student's) wasted time. Modifications will tend to be rather traumatic since they will generally involve replacement rather than expansion of the prior material.

A far safer, easier, and more effective approach makes use of student data at almost every step of development of the material. Rather than attempting to produce a finished product on the first try, the author provides only the skeleton necessary to permit gathering of student data. Straight instructional sequences consist only of brief presentations of information that the student is known not to possess. Where any question exists as to whether the student already *might* know certain information, only test items are included. Simulations need be represented only by mock-ups of minimal displays with selected information. Even functional simulations need have only minimal displays of information. As student data are collected, information is added only when proven necessary for the student to advance through the material.

As a result: the final product should allow students to progress at the most rapid effective rate; the author will have spent a minimum amount of time necessary for effective construction of material; and the material should be of proven effectiveness. Finally, students will be perceived as colleagues who provide useful information rather than as adversaries who perversely force changes in what was thought to be a finished product. This general approach is by no means unique to CBE. It is a technique (known as "lean programming") used extensively by authors of programmed instruction. The data-gathering and editing features of CBE, however, allow lean programming to be carried several steps beyond what is possible in standard programmed instruction.

INTRODUCING THE STUDENT TO CBE

There is a tendency for authors of CBE material to forget both the novelty of their initial interaction with the system and how rapidly this novelty wore off. As a result new students are frequently confronted with explanations, demonstrations or CBE instruction on use of CBE which, though initially extremely difficult, rapidly become boring.

The effect of initial confusion should not be underestimated. The student is confronted with a device which, at the very least, has large numbers of strangely labeled buttons on a keyboard. If the student has never used a typewriter before, this initial confusion is even greater. Interaction with the CBE system usually seems awkward at first. For example, the student will generally have to give an overt indication that a typewritten response has been completed. In normal conversation such "completion signals" are given almost automatically by inflection changes or pauses in speech. Communication with a computer however may require that a button on the keyboard be pressed to mark the end of a student's statement or response. The instruction "type your answer and press JUDGE" may be completely unambiguous (and probably unnecessary) for the experienced student who realizes that a key on the keyboard labeled "JUDGE" must be pressed to indicate completion of a response. A person not aware of this fact might type his answer and either search for such a key or, taking the instruction literally, press his finger against the word "JUDGE" on the display. On a CBE system which did not have provision for touch-sensing on its display, pressing the display might seem humorous to an experienced user. On a CBE system which did provide for such touch-sensing, the response might be the correct one. The important thing to remember is that the new student given ambiguous instructions in a novel situation has no real idea of which is the correct operation. While some students enjoy solving such problems,

many will not appreciate being placed in a situation in which they might make an absurd response. In an attempt to make the situation less ambiguous for the new user we might alter the instructions to read "type your answer and then press key JUDGE." Even here ambiguity is reduced only if the student knows that the confusing object with all the buttons in front of him is called a "keyboard" and the buttons are called "keys." Almost every group of students will include a few who have such problems. One solution might consist of an extensive and detailed instructional sequence, perhaps presented by CBE, which demonstrates and gives practice in using the CBE terminal. Such a solution has almost always proven to be a waste of time for all concerned. Except for illiterate students, only a few keys on the keyboard offer any problems. Even a non-typist will recognize the function of the "standard" numeric, alphabetic, punctuation, and numeric operation keys. Only special-operation keys and other input devices peculiar to that CBE terminal need an explanation. On very flexible or complicated terminals it is even unlikely that all of the special-operation keys or devices will be of immediate use to a student. What the student needs is not extensive practice in use of every possible feature of the terminal but rather some information which will let him know what subset of an overpowering array of new items is of immediate use. It should always be possible to function initially by use of a small number of special procedures or key presses. At most these special keys or procedures should number about 6, ideally they would number 3 or less. For example, on a system using a keyboard, it should be possible to go through an extensive amount of properly designed material using only a key which terminates responses and a key which allows erasure or overwriting of incorrect responses. Other special-function keys should be introduced *only* when needed and at the time they are first used. With such an approach it is generally possible to have new students functioning

in useful instructional material within a few minutes of first sitting at a terminal. It is also frequently helpful to provide a single-page instruction sheet which indicates (by use of a simple sketch) the location of special function keys or other features of the terminal and briefly describes their function. Remember that such handouts *must* be exceedingly clear, concise and simple. They are intended to clear up what appears to be complicated, rather than add to that burden. Probably the only valid exception to avoiding extensive special instruction on use of a CBE terminal itself occurs in the teaching of very young and/or illiterate students. Even in this case, it could be claimed that learning to identify the standard keys is a part of the desired instruction rather than merely preparation for instruction.

Almost a decade of evaluating student attitudes toward one very flexible CBE system (the PLATO system) has consistently shown that the major negative factor which students report has to do with hindrance of their progress through the instructional material. Most new students want to begin effective interaction with the system and course material at the earliest possible moment. Extensive practice in use of the terminal in contrived situations or even for spectacular demonstration sequences which are not related to the subject matter are not well accepted by students

A degree of anxiety can be expected on the part of some students when first faced with the idea of CBE. Such anxiety almost always disappears during the first period of use of CBE *if* the material is structured so that the student is not under extreme time pressure and *if* it is clear that every response during learning need not be correct the very first time. Even this natural early anxiety can be considerably reduced by use of a *very* brief and informal orientation talk or written note before students see the CBE terminals the first time (a long speech about why there is no reason for anxiety in those about to use CBE is, of course, likely to have an effect precisely opposite to that intended). Such an introduction is best presented as an explanation of why CBE has been chosen for the particular material

being taught. In the course of the explanation information can easily be given which will calm the two most prevalent fears of new users, namely

1. Use of CBE requires technical skills not held by the student, and
2. Use of a computer will somehow demean the student.

Both fears are best answered by citing evidence and comments from previous student users of the same material. If your material is properly designed and a true CBE system is being used, most students will feel that operation of the terminal requires less technical skill than operating a TV set. Typed responses generally make up such a minor portion of the time at a CBE terminal that the "hunt-and-peck" typist can progress as rapidly as a skilled typist (and, as an additional bonus learn the location of keys on the standard typewriter keyboard). Again assuming properly designed material, you should receive comments from students who appreciate the freedom of being able to progress at their own speed and of making errors in the course of learning without the instructor or other students knowing about it. On this last point it is well to emphasize to students (and yourself) the distinction between errors made during learning and those made during "test" or "work" situations. "Errors" made in the learning process are a natural part of that process and should actually be considered as part of an information-gathering procedure. As such they are the business of the student alone (and of the instructional author who is interested only in the "errors" and not in who made them). Only in a work or test situation where evaluation of individual student performance is a reasonable objective should the student have to worry about giving error-free responses.

If the material is still being revised - as will always be the case for most readers of this manual - students should be informed of this in a manner which makes it clear that their comments and recommendations are a valued and crucial part of the revision process.

DOCUMENTATION - TELLING THE WORLD ABOUT YOUR MATERIAL

Up to this point, evaluation has been directed toward development of the CBE materials as they go through their formative stages (in fact, such evaluation is termed "formative evaluation"). Eventually it is likely that the author will want to talk to "outsiders" about his material. He may wish to publish a description of the material in a professional journal, describe the results of his efforts for some agency which has supported his work, or tell potential users about it. All of these audiences will want to know;

(1) What is the material supposed to do?
(2) What approaches are used?
(3) Does the material succeed?
(4) What other things (good or bad) happen?

in addition to the details of unique interest to them alone. This common information is based on an evaluation of the sum-total effect of the program (and is termed a "summative evaluation"). Obviously there is overlap in the data used in formative and summative evaluations but a summative evaluation is, by the fact that it is directed to the needs of another audience, more than just a collection of formative data. The *author* wants to know, "how can I improve this particular material?" The *outsider* wants to know, "just how does this material differ from other material that is available?"

The generally recognized guidlines for a summative evaluation report on CBE materials are contained in a series of reports produced by a joint committee of experts from several professional organizations having a direct interest in instructional technology (the publication containing these reports has the following impressive citation - "Joint Committee on Programmed Instruction and Teaching Machines - AERA, APA, DAVI (NEA), *Recommendations for Reporting the Effectiveness of Programed Instruction Materials.* Washington: National Education Association, 1966"). While these guidlines are "unofficial" they do specify a set of require-

ments which we generally recognized as the minimum necessary for a useful validation report. If there is any chance that you will want to communicate the results of use of your material to others you should consult someone with evaluation experience well *before* using the material with large numbers of students. Without such prior consultation you may find yourself in the unfortunate position of having an excellent set of materials but not being able to convince anyone but your students of that fact.

Very briefly, the sorts of information required by Joint Committee Standards include matters such as:

(1) *Objectives* - A frank statement of what the material *is* expected to do and *is not* expected to do will save many misunderstandings. Objectives are most clearly stated in terms of the sorts of performances expected as a result of the instruction (note that objectives may also include behaviors other than those of students as well as outcomes other than behaviors). Criterion tests should be described completely and scoring keys provided for all or a highly representative sample of test items.

(2) *Required student background* - All assumptions of entry skills of beginning students should be clearly stated and a general indication of the intended population of users should be made.

(3) *Description of preliminary development* - The number and backgrounds of students used during the formative stages of your material should be indicated. While large numbers of students are not expected to be used during preliminary development, those used should represent the full range of abilities present in the intended final student populations.

(4) *Pre-and Posttests used in validation* - Complete copies of tests used (together with a description of the rationale used in their design) and scoring keys should be available. It is vital that relative difficulty levels of these tests be known as well as the degree of overlap between test items and elements of the material. Use of a pretest which is later found to be far more difficult than the posttest or use of a posttest loaded with items lifted directly from the instructional material may help an author's statistics but they do not help his reputation.

(5) *Results of a formal validation study* - The formal validation should be based on as large a group of students as feasible. It is extremely important that meaningful pretests be given to all students. This is particularly true in situations where comparisons are to be made between students receiving different instructional treatments. If it cannot be shown that groups were equivalent in all important factors prior to instruction, performance measures after the instruction will be difficult to interpret. The number and characteristics of "dropouts"

should similarly be noted. Comparisons between groups which have differing numbers or types of dropouts will generally require experienced statistical aid. Measures of total time spent, error rates, attitudes towards subject matter and method of presentations, as well as performance measures are needed for a complete interpretation of the outcome of the validation study.

Ultimately, almost every aspect of the material and its use can serve as data for a summative validation study. While results of student performance tests are important, they will not provide the complete picture that (say) a prospective user might want. It is exceedingly important to know about many effects which do not immediately involve the student. Attitudes of administrators or department heads may for example, determine the implementation (or nonimplementation) of a program independently of performance scores of students. In a realistic situation it is thus almost always a better idea to attempt a broad (though perhaps shallow) view than to obtain a view in depth of an aspect that tells only parts of the story.

FOR FURTHER INFORMATION

The books listed below have been selected on the basis of three criteria;

(1) *Clarity.* Much or all of the book should be useable by intellegent readers who do not have an extensive background in the area treated.

(2) *Breadth.* A variety of issues should be covered and references for further access to topics of particular interest should be provided.

(3) *Timeliness.* The book should reflect, insofar as meeting the first criterion allows, the most recent work in the field.

Research in both instructional techniques and evaluation methodology has expanded enormously during the past 15 years and many excellent references are available for those who are interested and have the time to read further. Perhaps the best source of information on these other references is your local expert in curriculum development or evaluation (depending on the topic). Even if such an expert is unavailable, the references listed below will certainly start you on your way.

Anderson, R. C. et al (Eds) *Current Research on Instruction.* Englewood Cliffs, N.J.: Prentice-Hall, 1969. An excellent collection of papers and reports on basic aspects of the instructional process.

Bloom, B. S. et al (Eds) *Handbook on Formative and Summative Evaluation of Student Learning.* New York: McGraw-Hill, 1971. A solid, practical guide to the basic techniques of evaluation of learning "...intended primarily for... classroom teachers." Includes many examples of applications of techniques.

Markle, S. M. *Good Frames and Bad, a Grammar of Frame Writing* (2nd ed.) New York: John Wiley, 1969. An introduction to the practical problems of designing effective interactions between student and subject-matter. The material is presented in the form of a "programmed text." While many of the examples given may not be appropriate for CBE, the general techniques are well worth consideration by CBE authors.